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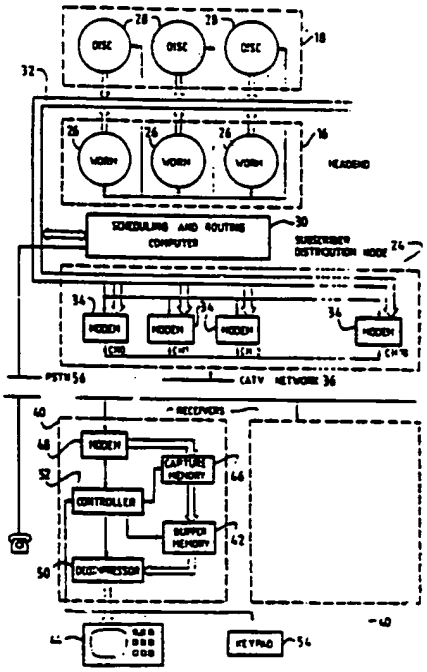
(57) Abstract

A system and method of optimising transmission of a program to multiple users over a distribution system, with particular application to video-on-demand for a CATV network (36). The system includes, at a head end of the CATV network (36) a scheduling and routing computer (30) for dividing the video program stored in long term fast storage (16) or short term fast storage (18) into a plurality of program segments, and a subscriber distribution node (24) for transmitting the program segments in a redundant sequence in accordance with a scheduling algorithm. At a receiver (40) of the CATV network (36) there is provided a buffer memory (42) for storing the transmitted video program segments for subsequent playback whereby, in use, the scheduling algorithm can ensure that a user's receiver (40) will receive all of the program segments in a manner that will enable continuous playback in real time of the program. Under the control of controller (52) the receiver (40) distinguishes received program segments by a segment identifier so that redundant segments captured in capture memory (46) are then stored in buffer memory (42) from which the segments can be retrieved and decompressed in data decompressor (50) for immediate or subsequent viewing.



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PROGRAM TRANSMISSION OPTIMISATION

FIELD OF THE INVENTION

The present invention relates to a system and method for program transmission optimisation over a distribution system and relates particularly, though not exclusively, to such a method and system for supplying video-on-demand over a cable television network.

DISCUSSION OF THE PRIOR ART

Throughout the following specification the word "program" should be understood in the broadest sense of the term and includes any information, whether visual or audible, a mixture of both or otherwise, which is normally perceived in a substantially continuous sequence of impressions through one or more of the human senses. The term "video program" refers to a program of visual information or visual and audible information, whether recorded in reproducible format or transmitted "live". In our "information society", with its increasing emphasis on greater accessibility to information, there are many situations where the same program may be required to be accessed by more than one person at the same time.

Thus, for example, in a library of a large educational institution which stores lectures and other information on audio and/or video cassettes, the demand for certain programs may be particularly high at certain times and there is a need to be able to allow several students to listen to or view the program simultaneously from the beginning, without having to force individuals to start listening to or viewing the program at the same time. Ideally, it should be possible to service the needs of all persons requiring that program immediately when it is requested. In practice this is extremely difficult without expensive duplication of equipment and complex electronic processing. Another example of this type of multiple user situation is so called video-on-demand television. A video-on-demand system ideally allows any subscriber to request (demand) any particular video program at

any time of the day.

A prior art video-on-demand system is described in U.S. 4,506,387 to Walter in which each video program is pre-programmed in a memory device selectable by a host computer at a central data station in response to an address signal transmitted from the user. The host computer controls the transmission of the video program at a high non-real-time rate over a fibre optic line network to a data receiving station at the users location. The data receiving station then converts the received optical data to electrical data and stores it for subsequent real-time transmission to the users television set.

There are a number of significant disadvantages with the system of Walter, the foremost being that it is incompatible with existing television transmission networks, and in particular CATV coaxial cable networks. In order to achieve a rapid response time Walter transmits all of the digital data corresponding to an entire program to the receiving station over a plurality of fibre optic lines within a very short time. Even with compression of the digital data the bandwidth requirement for this system is relatively large. For example, sixteen (16) optical data channels over four fibre optic lines are required to transmit a two hour movie in about thirty one seconds. Very few homes or buildings currently have ready access to a fibre optic cable, and a fibre optic network is expensive to install.

A further disadvantage with the system of Walter is that it cannot adequately handle a high demand for the same video program. Research in video tape lending libraries indicates that out of a total of say five thousand tapes held in the library, at any one time only a core group of twenty to forty most popular titles are in high demand. Furthermore, this research into the viewing habits of viewers indicates that the core video demand requirement varies throughout the day as the nature of the viewers changes. Whilst Walter contemplates that the central data station may transmit only a portion of the selected program to the user for his viewing, and then begin transmitting a portion of another selected program to a second user, the system cannot simultaneously handle several

users requesting the same program. In that event, a user must wait until transmission of the entire program to each user who placed a request prior to his own has been completed, before the system can attend to his demand. Clearly with core video programs this could result in unacceptable delays.

SUMMARY OF THE INVENTION

The present invention was developed with a view to providing a method and system for program transmission optimisation over a distribution system for multiple users, and was developed specifically, though not exclusively, with a view to providing a system and method for supplying video-on-demand which is compatible with existing video distribution systems such as CATV. Throughout this specification the term "distribution system" is to be construed in the broadest sense of the term and covers ordinary radio and television networks, CATV and internal television/video/audio distribution systems of the kind employed in hotels, educational institutions and more recently in aircraft and ocean liners.

According to one aspect of the present invention there is provided a method for optimising transmission of a program to multiple users over a distribution system, the method comprising:

at a head end of the distribution system,

dividing the program into a plurality of program segments; and,

transmitting the program segments in a redundant sequence in accordance with a scheduling algorithm; and at a receiver of the distribution system,

storing the transmitted program segments in a buffer storage means in the receiver for subsequent playback whereby, in use, said scheduling algorithm can ensure that a user's receiver will receive all of the program segments in a manner that will enable continuous playback in real time of the program.

Preferably the method further comprises selecting a Maximum Response Time (MRT) corresponding to a maximum time a user need wait to commence playing a requested program.

Typically the step of dividing the program involves dividing the program into segments of a length selected such that at least one segment can be transmitted in the time of one MRT.

In the preferred embodiment said step of transmitting the segments involves transmitting one or more segments during each MRT, including a first segment corresponding to a first segment of playing time of the program, in accordance with the scheduling algorithm whereby, in use, the first segment is always available at a receiver within one MRT for immediate playback.

According to another aspect of the present invention there is provided a system for optimising transmission of a program to multiple users, the system comprising:

at a head end of the system:

means for dividing the program into a plurality of program segments; and,

means for transmitting the program segments in a redundant sequence in accordance with a scheduling algorithm;

and at a receiver of the system,

buffer storage means for storing the transmitted program segments for subsequent playback on the receiver whereby, in use, said scheduling algorithm can ensure that the receiver will receive all of the program segments in a manner that will enable continuous playback in real time of the program at the receiver.

Preferably the system further comprises at the head end of the system:

means for numbering the program segments 1 to n, where n equals the number of segments into which the program is divided, and wherein the segments are numbered in the order in which they should appear in the program for normal playback.

According to a further aspect of the present invention there is provided a receiver for receiving a program supplied by a program transmission optimisation system, the

receiver comprising:

buffer storage means for storing a plurality of program segments of the program transmitted from a head end of the system according to a scheduling algorithm; and,

processing means for processing said program segments stored in the buffer storage means and supplying the segments in the correct sequence for playback whereby, in use, said scheduling algorithm can ensure that the receiver will receive all of the program segments in a manner that will enable continuous playback in real time of the program at the receiver.

Typically said processing means comprises means for distinguishing received program segments by a segment identifier, wherein said segment identifier at least identifies a segment by its number whereby, in use, the receiver can distinguish redundant segments from segments required for subsequent playback.

According to a still further aspect of the present invention there is provided a scheduling apparatus for a program transmission optimisation system, the apparatus comprising:

means for dividing the program into a plurality of program segments;

means for scheduling said plurality of program segments in a redundant sequence in accordance with a scheduling algorithm; and,

means for routing said scheduled program segments for transmission to one or more receivers of users requesting the program whereby, in use, said scheduling algorithm can ensure that a user's receiver will receive all of the program segments in a manner that will enable continuous playback in real time of the program.

Preferably said means for dividing divides the program into segments of a length selected such that at least one segment can be transmitted in a Maximum Response Time (MRT) time interval, wherein MRT corresponds to a maximum time a user need wait to commence playing a requested program from its beginning.

The scheduling algorithm preferably employed in the invention involves iteratively calculating during each MRT the result of COUNT Modulo X= Y, wherein COUNT = a predetermined initial whole number incremented by 1 each MRT, X=1 to n, where n = the number of segments into which the program has been divided, whereby, in use, wherever Y=0 the program segment number X will be transmitted.

BRIEF DESCRIPTION OF DRAWINGS

In order to facilitate a better understanding of the nature of the invention a detailed description of one preferred embodiment of a program transmission optimisation system and method in the form of a video-on-demand system and method will now be given, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of a preferred embodiment of a video-on-demand system;

Figure 2 is a more detailed block diagram illustrating the functional blocks of the video-on-demand system in Figure 1 applied to a CATV network;

Figure 3 is a flow chart of the method steps employed at a head end of the video-on-demand system;

Figure 4 is a flow chart of the method steps employed at a receiver of the video-on-demand system;

Figure 5 is a tabular representation of the transmission sequence of video segments in accordance with a preferred scheduling algorithm; and,

Figure 6 is a graphical representation of the relationship between Maximum Response Time and the required video-hours/hour of transmission time.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Figure 1 illustrates schematically a preferred embodiment of the video-on-demand system according to the present invention. Referring to Figure 1, external non-compressed material can enter the system in its most basic format such as 35mm film, video tape, or through a telecommunications link such as broadcast television or

satellite transmission. The non-compressed material is passed through a media compression system 10 for compressing the audio visual program material into a compressed format. The audio visual program material may be compressed by an external video compression service provider, such as Intel Corporation. Such external compressed material may enter the system directly via a storage distribution node 12. The storage distribution node 12 routes the compressed video material to the appropriate storage medium.

There are three types of storage in the system, long term slow storage 14, long term fast storage 16 and short term fast storage 18. The division of the storage of compressed video material into the different types of storage is based on commercial considerations, in view of the relatively high cost of fast storage media compared to slow storage media. The selection of the type of storage to which different programs would be routed is based upon the expected future demand for the video material concerned. Daily news segments would probably be stored in short term fast storage 16, whereas a movie classic such as "Gone With The Wind" would probably be stored in long term fast storage 16. Infrequently requested materials such as some obscure silent movie would probably be stored in long term slow storage 14. The storage distribution node 12 is typically a micro or mini computer which controls the flow of data between the different storage devices.

The long term slow storage 14 typically takes the form of storage media such as magnetic tapes, or optical discs and may require human intervention for retrieval of infrequently accessed program material. The long term fast storage 16 may typically take the form of a jukebox type of optical disc storage device. Optical disc storage provides high density storage with random access, and the jukebox access mechanism provides automatic program access. A typical unit currently available is the KODAK Optical Disc System 6800 drive/cabinet. The short term fast storage 18 may take the form of a magnetic disc drive such as an IBM Model 3380. This allows rapid random access to the compressed video material stored in digital format, but is a relatively expensive storage

medium and would therefore only be used for storing popular core video programs.

The scheduling and routing computer 20 receives requests for specific audio visual material from user's receivers 22A, 22B or 22C via a bi-directional request and distribution network. The scheduling and routing computer 20 controls the retrieval and division of the selected video program in a plurality of video segments, schedules the video segments in accordance with a scheduling algorithm and controls the routing of the scheduled segments for transmission to one or more of the receivers 22A, 22B or 22C, so that each requesting viewer's receiver will receive all of the video segments in a manner that will enable continuous immediate viewing of the program. The video-on-demand system employs a combination of frequency multiplexing and time division multiplexing. The time division multiplexing of the video segments is controlled by the scheduling and routing computer 20 in accordance with the scheduling algorithm. The frequency multiplexing is performed by a subscriber distribution node 24 under the control of the scheduling and routing computer 20. The processing capabilities of the scheduling and routing computer 20 are similar to that required by computers used by banks for automatic teller machines. The scheduling and routing computer 20 may be any suitable computer with a typical processing capability of 1.5 to 200 million instructions per second (MIPS), depending on the size of the subscriber base and other loading factors.

The viewer's receivers 22 are typically frequency agile, to be compatible with the frequency multiplexing employed at the head end of the system. The receivers are provided with processing means to capture the appropriate data packets created by the time division multiplexing of the video segments. The receivers 22 are also provided with buffer storage means for storing the received video segments, and would typically also comprise decompression means for decompressing the video data for subsequent display on a dedicated television screen, or fed into a conventional television set.

The video-on-demand system of Figure 1 can operate on either analog or digital communication circuits, however in the preferred embodiment described below the video distribution system is a conventional cable television system which is analog. In the preferred embodiment of the system described below primarily modulated digital data is transmitted over the CATV network. However, it is envisaged that a future system will employ a mixture of analog and modulated digital signals.

The method of program transmission optimisation according to the invention can provide transmission optimisation for either digital or analog information signals.

Conventional CATV systems are typically simplex communication systems (one way only) so that there is no easy way to retransmit data when errors are detected. Accordingly, some form of error compensation is required. Fortunately, television data is generally used in a very transient manner, unlike computer data that must be assured of accurate transmission. If a few frames of a TV image are disturbed most viewers accept this without even a conscious acknowledgment of their occurrence. Accordingly, a much higher bit error rate can be tolerated, for example 1 erroneous data bit per 100,000. At this rate the human eye/brain system normally cannot even detect the video effects caused by this erroneous bit. Most digital modems work with bit error rates of 1 in 100,000,000 to 1 in 1,000,000,000! Therefore, the video-on-demand system can tolerate error rates typically from 1,000 to 10,000 times higher than most computer data systems are presently designed for. A higher error rate will of course improve performance, although the improvement may be imperceptible to a viewer.

Figure 2 illustrates in block diagram form a preferred embodiment of the video-on-demand system applied to a CATV network. The video demand system comprises at the head end means for providing a video program in a compressed format in the form of Write Once Read Many (WORM) storage devices and magnetic disc storage devices 28 providing long term fast storage 16 and short term fast storage 18 respectively. In this particular embodiment the compressed video material is stored in digital format in the storage devices and the video

programs may already be segmented in the storage media in video packets sized to be compatible with the system specifications. The magnetic disc devices 28 and WORM devices 26 are connected to a scheduling and routing computer 30 by data bus 32.

The scheduling and routing computer 30 responds to a subscriber request for a particular program by retrieving the video program from the appropriate storage media and dividing the video program into a plurality of video segments. As mentioned above, the video program may be stored in the storage media already in segments corresponding to the scheduling requirements of the system thereby reducing the load on the computer 30 during the process of retrieving and dividing the video program into video segments. The computer 30 then schedules the plurality of video segments of the video program in accordance with a scheduling algorithm, as will be described in more detail below, and routes the scheduled video segments for transmission to one or more receivers of viewers requesting the video program. For core video programs (those that are in continuous demand by at least one subscriber for periods of more than one Video Playing Time (VPT)), the scheduling algorithm can be run once and the packets stored in the scheduled sequence on a serial recording device such as a tape drive (not shown), to further reduce loading on the computer.

In this embodiment the subscriber distribution node 24 comprises a plurality of modems 34 under the control of the scheduling and routing computer 30. Each modem 34 modulates a different carrier frequency signal, corresponding to each of the channels on the CATV network 36, for transmitting the video segment data packets routed to the appropriate modem 34 by the scheduling and routing computer 30 over data bus 32.

Each subscriber on the CATV network 36 is provided with a receiver 40 for receiving the video segment data packets corresponding to the requested program and storing the video segments for future viewing by the subscriber. Each receiver 40 typically comprises a buffer memory 42 for storing the video segments of the video program transmitted from the head end, and video processing means for processing the video segments stored in the buffer memory and supplying the segments in the

correct sequence to a subscriber television set 44 for viewing. Typically the video processing means may include a controller 52 and a capture memory 46 for capturing the video segment data packets received over the CATV network 36 and demodulated by one or more modems 48 of the receiver. Under the control of controller 52 the video processing means distinguishes received program segments by a segment identifier, for example the PKT ID, so that redundant segments can be ignored and overwritten in capture memory 46. Modem 48 is preferably a frequency agile broad band modem such as the Fairchild M505, although as noted above a more low level digital modem with lower bit error rate can also be employed. Compressed video data packets captured in capture memory 46 are stored in buffer memory 42 from which the segments can be retreived and decompressed in data decompressor 50 for immediate or subsequent viewing. The microprocessor based controller 52 controls the flow of data and the video processing within the receiver 40.

Some CATV systems can accommodate bidirectional decoders or receivers, and for this type of system the receiver 40 is provided with a key pad 54 to enable the subscriber to initiate a request via the CATV network 36. However, the majority of CATV systems are unidirectional (simplex) and a subscriber request must therefore be made over the public switched telephone network (PSTN) 56. The subscriber request via the PSTN 56 may be verbal or via touch tone keying similar to that provided by other on-line subscriber network service providers.

Security on the system to prevent unauthorised viewing of transmitted programs may be implemented in several ways. Standard encryption algorithms could be applied at the modems 34 prior to transmission. Each receiver 40 would then require a key to decrypt the received data. Encryption/ decryption keys are distributed to subscribers in a similar manner to that employed by financial institutions to distribute PINs for automatic teller machine usage. Alternatively, each data packet transmitted at the head end can be prefixed with a receiver ID unique to each subscriber so that a pirate receiver would need to select the appropriate receiver ID in

order to receive a particular video program.

It will be appreciated that the video-on-demand system illustrated in Figure 2 is exemplary only, and that many other hardware implementations could be employed to effect the method and system for supplying video-on-demand according to the invention. For example, the receivers 40 may comprise several modems for simultaneously receiving data packets over several channels, and the capture memory may be dispensed with if the video segments are stored in the buffer memory in compressed format. The video segments are then decompressed when they are provided to the subscriber's television set in the correct sequence for viewing. Furthermore, certain sections of the head end apparatus or of the receiver may be located at different geographical locations. For example, in view of the typical architecture of CATV systems, it is possible that the modem and buffer sections of the receiver will become part of the cable network in what is referred to as a subscriber tap, and that the other sections would be located at the subscriber's premises.

It should be noted that the video segment data packets for a particular program need not be transmitted over the same channel for all viewing subscribers. By employing a combination of time division multiplexing and multiple channels at the head end of the system, data rates over each of the channels can be kept at a minimum therefore allowing the use of less expensive hardware at the receivers. Each receiver 40 may be configured to scan the channels in a cyclic fashion in order to determine which channel or channels the appropriate video segments are being transmitted. In addition to this a dedicated control channel can be provided over which data from the scheduling and routing computer 30 is transmitted to instruct each receiver as to which packets to receive and on which channel(s). However, preferably the head end transmits the video segments in accordance with the scheduling algorithm in a continuous manner, with each video segment provided with a title ID as well as a segment ID, so that each receiver will receive all of the video segments with the appropriate title ID and can discard or overwrite the video segments already

received.

A key feature of the present invention is the scheduling of the video segments for transmission in a redundant sequence in a manner that will ensure that each receiver will receive all of the video segments for the requested program according to a schedule that will enable continuous playback in real time of the video program at the receiver. A preferred form of an efficient scheduling algorithm and its implementation will now be described in detail.

In the following description the term "Maximum Response Time" (MRT) refers to the maximum time a subscriber will need to wait before the video program requested will be available for viewing at his receiver. MRT refers to the maximum time that the system has to respond to the demand. Video Play Time (VPT) refers to the time required to play the particular video program when viewed at normal play back speed. The data that comprises the video program must be divided into video segment data packets of such a length that one packet can be transmitted in the time of 1 MRT. The video segment play back time or slot length of one data packet need not be less than 1 MRT and may be longer than 1 MRT depending on how much band width is available over the transmission medium for transmitting the data packet(s) in the time of 1 MRT. The slot length may be variable in order to adjust the instantaneous loading and data rates on the transmission medium or to adjust the amount of buffer storage space required in the receivers. However, in any one installation, the slot length and MRT would normally be fixed for a specific system configuration. In the following description the slot length has been made equal to the MRT in order to simplify explanation. Thus, for example, if the video program is 60 minutes long and the MRT is 5 minutes, the video program is divided into 12 discreet data packets each corresponding to 5 minutes of video segment data. Each of the data packets is numbered from 1 to n where n equals VPT/MRT, in chronological viewing order.

Implementation of the scheduling algorithm is preferably under software controlled by the scheduling and

routing computer 30. The basic flow of the scheduling program is as follows:

```
          set MRT equal to chosen maximum response time
          set a counter equal to 0 an initial value
          retrieve video segment data packets sized to relate
          to a play time of MRT (PKT1, PKT2 ....PKTn).
loop      wait for remainder of period equal to MRT
          set COUNT equal to COUNT plus 1
          if (COUNT Modulo 1) = 0 then transmit PKT1
          if (COUNT Modulo 2) = 0 then transmit PKT2
          if (COUNT Modulo 3) = 0 then transmit PKT3
          ........................................
          ........................................
          ........................................
          if (COUNT Modulo n) = 0 then transmit PKTn
          start again at loop
```

Note: (x Modulo y) = the remainder of (x divided by y).

In accordance with the above scheduling algorithm video segment data packets are transmitted in a redundant sequence, with one or more data packets being transmitted during each MRT. Each transmission starts at an incremental time n*MRT, and in many instances a majority of the MRT period is expended in actually accomplishing the transmissions. With the above scheduling algorithm PKT1 will always be transmitted, however the other packets may or may not be transmitted at any given value for COUNT. Hence, any particular requesting receiver may receive the packets in a non-contiguous stream. Thus, for an MRT = 5 and a VPT = 60 it may receive the packets as follows:

MRT	PKTs Received	PKTs Viewed
1	PKT1 AND PKT3	PKT1 VIEWED
2	PKT2	PKT2 VIEWED
3	PKT4 AND PKT8 AND PKT12	PKT3 VIEWED
4	NO PACKETS	PKT4 VIEWED
5	PKT5 AND PKT6 AND PKT7 AND PKT11	PKT5 VIEWED
6	NO PACKETS	PKT6 VIEWED
7	NO PACKETS	PKT7 VIEWED
8	PKT9 AND PKT10	PKT8 VIEWED

9	PKT9 VIEWED
10	PKT10 VIEWED
11	PKT11 VIEWED
12	PKT12 VIEWED

The above sequence is just one of many possible packet delivery sequences produced by the algorithm. Figure 6 is a graphical representation of the sequence of video segment data packets transmitted during each MRT time interval. The number of each video segment appears on the vertical axis and the number of the MRT interval appears along the horizontal axis. Figure 6 shows a maximum of 30 video segments and 49 MRT intervals, however obviously these are arbitrary numbers and both axes could be continued indefinitely. There would be a practical limit to the number of video segments that the video program could be divided into, however the number of MRT intervals will be a function of the duration for which a particular program is in continuous demand. From casual observance of the sequence output of the algorithm it would appear to be a random ordering of packets. However, although the sequence may be considered pseudo-random, it is in fact non-random in that it ensures that a receiver never has to wait on any packet to be transmitted and can provide immediate viewing of the video segments in the correct sequence. Accordingly, by the time the receiver is ready to display a particular packet, that packet will either be in the buffer memory, or being received at that time.

In the above table, redundant packets have not been included in the "PKTs received" column since in practice these would be discarded or overwritten by the receiver. In the above sequence example it will be noted that within a time equal to 8 MRTs all 12 packets have been received, and that certain packets, for example PKT12, is received by the receiver well before it is needed for viewing. PKT12 and any other packets received early are held in the buffer until the appropriate time for viewing. The scheduling algorithm ensures that a packet is always received when it is due to be viewed or before.

In Figure 6, it can be seen that at certain times, for example, MRT intervals 12, 24 and 36 a larger number of packets are received than at other times, which tends to increase the load on the transmission medium and the buffer memory in the receivers. It is preferable that the buffer memory be large enough to store all of the data packets for a particular program, and this also enables the receiver to store the program for later viewing if desired.

The underlying design considerations for the scheduling algorithm and the amount of buffer memory required in the receivers involve trade off's between the response time (MRT) guaranteed to viewers, the bandwidth required for servicing requests, and the amount of buffer storage space provided in the receivers. The principle advantage of a scheduling algorithm of the above kind is the efficient utilisation of the transmitting medium that can be realised. Thus, for example, if an MRT of 5 minutes is required, without the scheduling algorithm the complete video program would need to be transmitted continuously from the beginning every 5 minutes. Thus, for a program with 60 minutes play time the complete program would have to be transmitted 12 times. Using the above scheduling algorithm the number of data packets required to be transmitted to provide an MRT of 5 minutes is equal to having to transmit the entire program only 3.12 times.

The relationship between MRT and the total amount of data that must be transmitted can be represented by the following "best fit curve" equation:

$$\text{TOTAL DATA} = \frac{\text{LOG (MRT/154.94)}}{-\ 0.47782}$$

Total data is in terms of VPT, so that a data amount of 3 is equal to 3 times the VPT or 180 minutes worth of data for a 60 minute program supplied with an MRT of 5 minutes. Figure 6 is a graphical representation of the relationship between MRT and the required video-hours/hour of transmission time or the total amount of data transmitted.

It will be appreciated that although the above described scheduling algorithm is the preferred form, modifications can be made to the algorithm that would allow

trade off's between transmission efficiency and the amount of buffer storage required. Commercial considerations will determine how the balance of system costs are weighted. If more is spent on receiver buffers, then less will be required to be spent on provision of transmission lines.

In an example of a modified scheduling algorithm it is possible to diverge from the requirement of always sending PKT1. In this case, PKT1 and other selected packets may be transmitted less frequently and held in available buffer storage space at the receivers until a request is lodged. For example, the following implementation can be adopted:

Each receiver is provided with low power buffer memory devices which are kept active at all times for receiving selected packets of video programs. Assuming there are, say, 10 core video programs, the receivers can be configured to store PKT1 of each of the 10 core video programs, PKT1 being only transmitted at predetermined intervals in accordance with the modified scheduling algorithm, rather than at each MRT as in the above described scheduling algorithm. Hence, when a request for a core program is lodged, the first packet is already in the receiver buffer memory and can be immediately accessed for viewing while the modified scheduling algorithm is then implemented. This can reduce transmission bandwidth requirements considerably, with a modest increase in receiver cost, while providing instantaneous delivery of the core program to the viewer.

It is also possible to reduce peak transmission loads by diverging from the requirement that all requests start to be serviced within a maximum period equal to MRT. By accepting a small percentage of service delays, it is possible to further smooth the transmission load.

A typical software control sequence at both the head end computer and at the receiver will now be described with reference to Figures 3 and 4. When the head end scheduling and routing computer receives a subscriber request it records the subscriber ID, the requested program title ID and the time of request. The computer tracks each request and its progress towards completion in accordance with the scheduling algorithm.

There will normally be several program streams being transmitted at any one time. The scheduling algorithm generates different data rates at different times as noted above. By staggering the entry value of COUNT for different program streams, the total data rate on the transmission medium can be maintained at a fairly constant level. Depending upon the value of COUNT at which a particular request enters the algorithm, the time taken to complete transmission of a requested program may range from 1 MRT to 1 VPT or any value in between.

Hence, when the head end computer has recorded the subscriber ID, title ID and time of request it determines whether the requested program is currently active, and if so enters the scheduling sequence at the conclusion of the current MRT time interval. If the requested program is not currently active then the COUNT value of the computer's internal counter, (may be a software counter) is set to the appropriate initial value to provide a staggering of the entry value of COUNT for each different program stream. Thus, for example, assuming requests are made simultaneously for programs A, B, C and D, service of the four requests can all commence simultaneously. However, program A would enter the algorithm scheduling sequence with COUNT equal to zero, B with COUNT equal to 1, C with COUNT equal to 2 and D with COUNT equal to 3. Thus, during each MRT time interval different numbers of video segments for each of the programs would be transmitted simultaneously, rather than the same number of video segments for each respective program.

At the commencement of the next MRT interval the computer enters the scheduling algorithm program sequence noted above and schedules the data packets for the title requested as per the scheduling algorithm. The computer also appends the title ID and packet ID to each data packet. The computer then selects a free channel and routes the data packets to the corresponding modem for transmission to the requesting receivers. The head end computer follows this sequence of steps until all of the packets for the requested title have been transmitted since the time of the last request for this

title. As soon as the computer has determined that all pending requests have been satisfied, no further data packets for that program are transmitted.

At the receiver, after the subscriber has sent a request the receiver scans the transmission channels and looks for the title ID. When the receiver finds the title ID it looks for the packet ID and stores any packets not already received in the buffer storage. If a packet has already been received this packet is discarded and the receiver continues to look for the remaining data packets until all the data packets for the video program have been received. Data packets stored in the buffer storage may be sent to the receiver directly for immediate viewing or stored for later viewing. Although not illustrated in Figure 4, the receiver may also be configured to look for its unique address ID to provide a degree of security against unauthorised data reception.

From the above description of a preferred embodiment of the program transmission optimisation comprising a system and method of supplying video-on-demand it will be apparent that the scheduling algorithm employed provides an efficient means of transmitting a program to multiple requesting subscribers who can commence playback of the program within a specified maximum response time. It will be apparent to those skilled in the electronics, television and telecommunication arts that numerous modifications and alterations may be made to the program transmission optimisation system and method, other than those already described, without departing from the basic inventive concepts. For example, in alternative realisations of the system and method an optical fibre network may be employed for the distribution system, for example, to provide programming on demand for aircraft passengers. Furthermore, the system and method can operate using analog communications as well as digital, or a mixture of both. Although in the video-on-demand system described the video program segments are transmitted in compressed format, this is obviously not an essential feature of the invention, since significant improvements in transmission efficiency can be achieved by relying upon the scheduling algorithm alone. All

such modifications and alterations are to be considered within the scope of the present invention the nature of which is to be determined from the foregoing description and the appended claims.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method for optimising transmission of a program to multiple users over a distribution system, the method comprising:

at a head end of the distribution system,

dividing the program into a plurality of program segments; and,

transmitting the program segments in a redundant sequence in accordance with a scheduling algorithm;

and at a receiver of the distribution system,

storing the transmitted program segments in a buffer storage means in the receiver for subsequent playback whereby, in use, said scheduling algorithm can ensure that a user's receiver will receive all of the program segments in a manner that will enable continuous playback in real time of the program.

2. A method as claimed in claim 1, further comprising the step of selecting a Maximum Response Time (MRT) corresponding to a maximum time a user need wait to commence playing a requested program from its beginning.

3. A method as claimed in claim 2, wherein said step of dividing the program involves dividing the program into segments of a length selected such that at least one segment can be transmitted in the time of one MRT.

4. A method as claimed in claim 3, wherein said step of transmitting involves transmitting one or more segments during each MRT, including a first segment corresponding to a first segment of playing time of the program, in accordance with the scheduling algorithm whereby, in use, the first segment is always available at a receiver within one MRT for immediate viewing.

5. A method as claimed in claim 4, further comprising at the head end of the distribution system the step of

numbering the program segments 1 to n, where n equals the number of segments into which the program is divided, and wherein the segments are numbered in the order in which they should appear in the program for normal playback.

6. A method as claimed in claim 5, wherein the scheduling algorithm involves iteratively calculating during each MRT the result of:

COUNT Modulo X = Y,

wherein COUNT = a predetermined initial whole number incremented by 1 after each MRT;

X = 1 to n, where n = the number of segments into which the program has been divided;

whereby, in use, whenever Y=0, the program segment number X will be transmitted.

7. A method as claimed in claim 1, further comprising the steps of recording a user identification number, a program title identification number and a time of each request in a subscriber request map; and, tracking each request and its progress towards completion.

8. A system for optimising transmission of a program to multiple users, the system comprising:

at a head end of the system:

means for dividing the program into a plurality of program segments; and,

means for transmitting the program segments in a redundant sequence in accordance with a scheduling algorithm;

and at a receiver of the system,

buffer storage means for storing the transmitted program segments for subsequent playback on the receiver whereby, in use, said scheduling algorithm can ensure that the receiver will receive all of the program segments in a manner that will enable continuous playback in real time of the program at the receiver.

9. A system as claimed in claim 8, further comprising at the head end of the system:

means for numbering the program segments 1 to n, where n equals the number of segments into which the program is divided, and wherein the segments are numbered in the order in which they should appear in the program for normal playback.

10. A system as claimed in claim 9, further comprising at the head end of the system:

means for appending a segment identifier to each program segment prior to transmitting, wherein said segment identifier at least identifies a program segment by its number.

11. A system as claimed in claim 8 or 9, wherein said means for transmitting transmits one or more of said program segments during each Maximum Response Time (MRT) time interval, wherein MRT corresponds to a maximum time a user need wait to commence playing a requested program.

12. A system as claimed in claim 11, further comprising at the head end of the system:

means for iteratively calculating during each MRT the result of the scheduling algorithm:

COUNT Modulo X = Y,

wherein COUNT = a predetermined initial whole number incremented by 1 after each MRT;

X = 1 to n, where n = the number of segments into which the program has been divided;

whereby, in use, whenever Y=0, the program segment number X will be transmitted.

13. A receiver for receiving a program supplied by a program transmission optimisation system, the receiver comprising:

buffer storage means for storing a plurality of program segments of the program transmitted from a head end of the system according to a scheduling algorithm; and,

processing means for processing said program segments

stored in the buffer storage means and supplying the segments in the correct sequence for playback whereby, in use, said scheduling algorithm can ensure that the receiver will receive all of the program segments in a manner that will enable continuous playback in real time of the program at the receiver.

14. A receiver as claimed in claim 13, where said processing means comprises means for distinguishing received program segments by a segment identifier, wherein said segment identifier at least identifies a segment by its number whereby, in use, the receiver can distinguish redundant segments from segments required for subsequent playback.

15. A receiver as claimed in claim 13 or 14, wherein said processing means further comprises decompressing means for decompressing compressed program segments transmitted from the head end of the program transmission optimisation system.

16. A scheduling apparatus for a program transmission optimisation system, the apparatus comprising:

means for dividing the program into a plurality of program segments;

means for scheduling said plurality of program segments in a redundant sequence in accordance with a scheduling algorithm; and,

means for routing said scheduled program segments for transmission to one or more receivers of users requesting the program whereby, in use, said scheduling algorithm can ensure that a user's receiver will receive all of the program segments in a manner that will enable continuous playback in real time of the program.

17. A scheduling apparatus as claimed in claim 16, wherein said means for dividing divides the program into segments of a length selected such that at least one segment can be transmitted in a Maximum Response Time (MRT) time interval, wherein MRT corresponds to a maximum time a user need

wait to commence playing a requested program from its beginning.

18. A scheduling apparatus claimed in claim 17, further comprising means for numbering the program segments 1 to n, where n equals the number of segments into which the program is divided, and wherein the segments are numbered in the order in which they should appear in the program for normal playback.

19. A scheduling apparatus as claimed in claim 18, further comprising means for iteratively calculating during each MRT the result of the scheduling algorithm:

COUNT Modulo X = Y,

wherein COUNT = a predetermined initial whole number incremented by 1 after each MRT;

X = 1 to n, where n = the number of segments into which the program has been divided;

whereby, in use, whenever Y=0, the program segment number X will be transmitted.

20. An apparatus as claimed in claim 16, wherein said means for dividing retrieves the program segments from a compressed program storage means wherein the program is stored in segmented format corresponding to said plurality of segments.

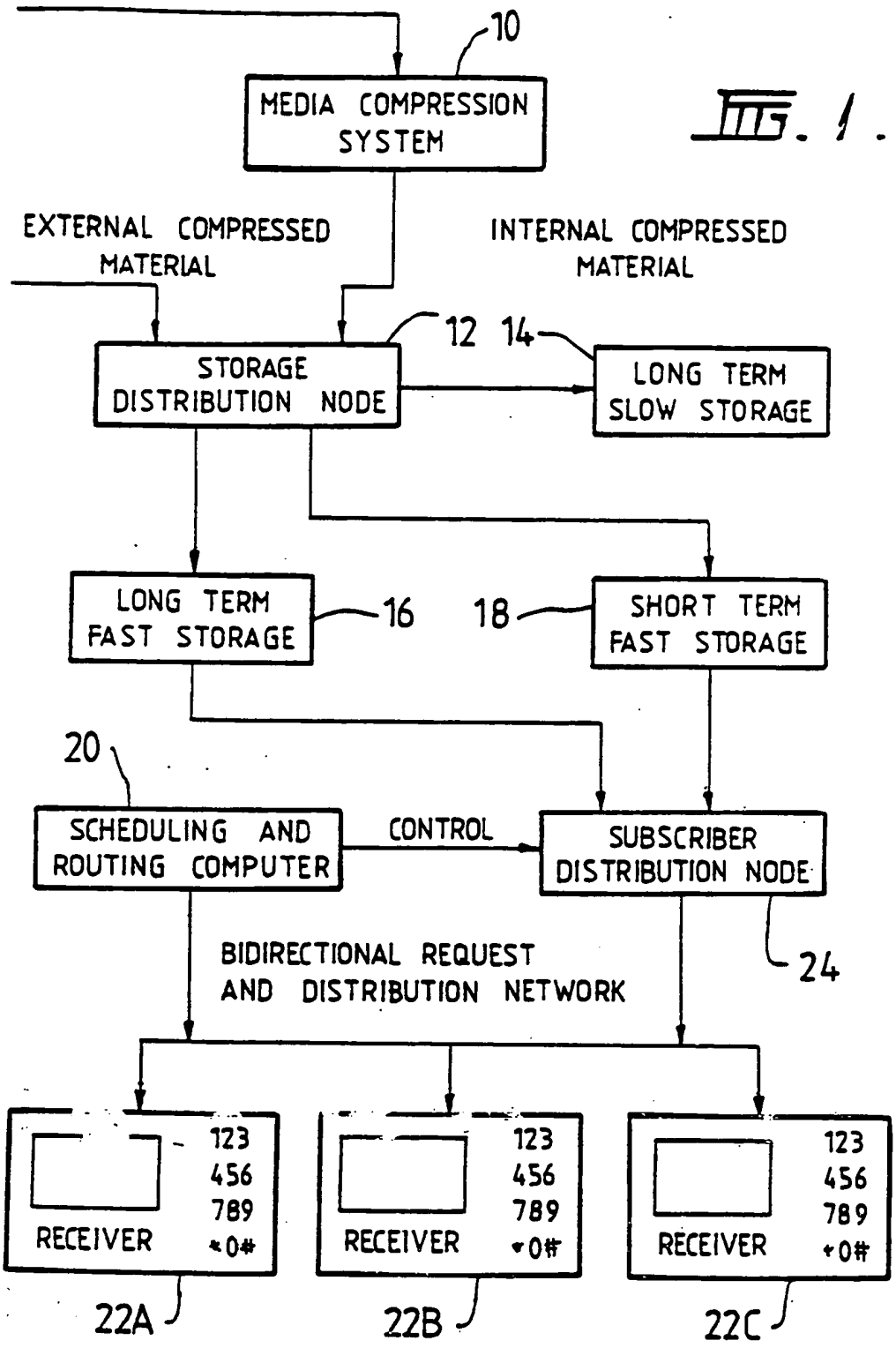
EXTERNAL NON-COMPRESSED MATERIAL
10
MEDIA COMPRESSION SYSTEM
EXTERNAL COMPRESSED MATERIAL
INTERNAL COMPRESSED MATERIAL
12
14
STORAGE DISTRIBUTION NODE
LONG TERM SLOW STORAGE
LONG TERM FAST STORAGE
16
18
SHORT TERM FAST STORAGE
20
SCHEDULING AND ROUTING COMPUTER
CONTROL
SUBSCRIBER DISTRIBUTION NODE
24
BIDIRECTIONAL REQUEST AND DISTRIBUTION NETWORK
123
456
789
*0#
RECEIVER
22A
22B
22C

FIG. 1.

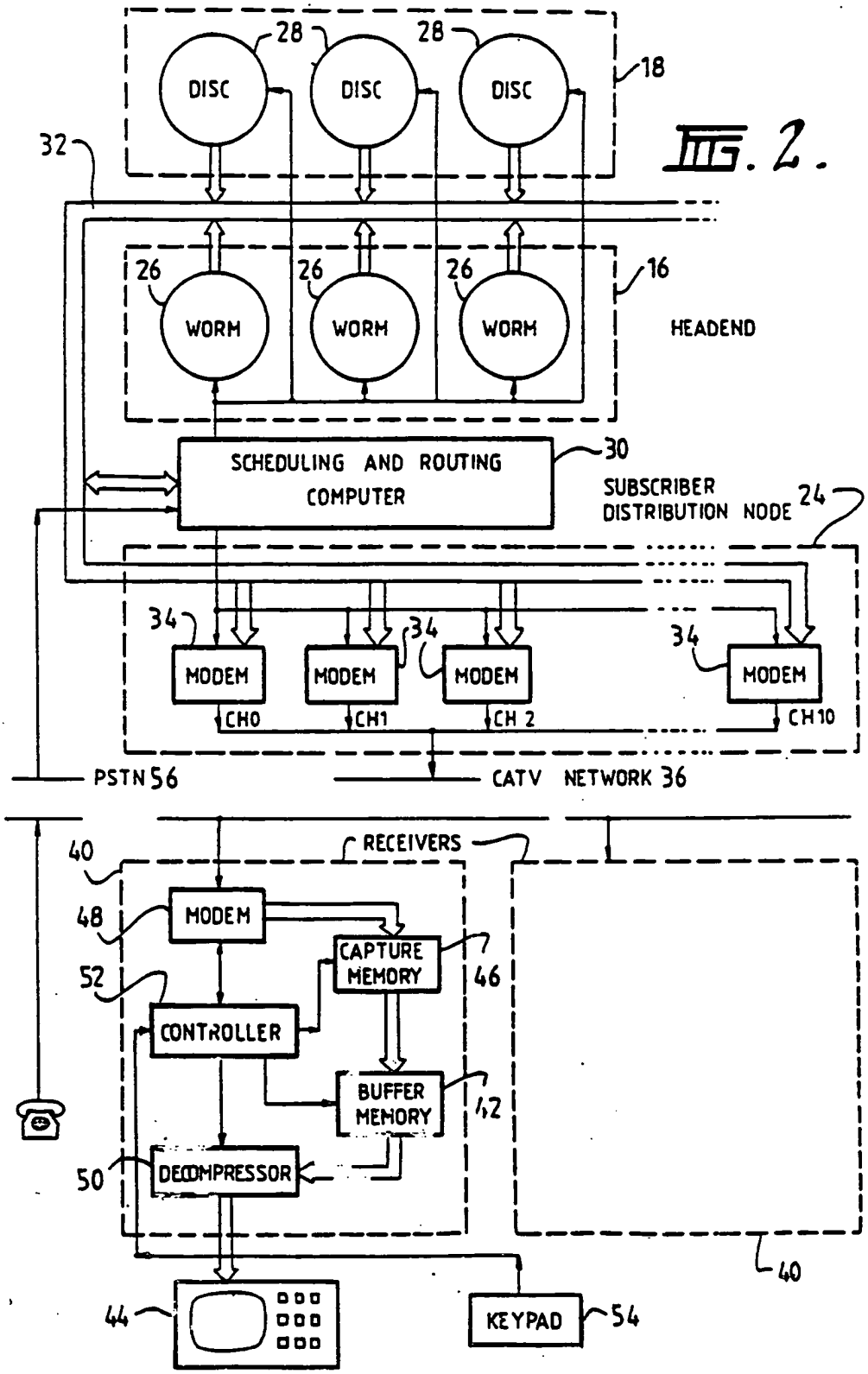
DISC
DISC
DISC
28
28
18
32
26
26
26
WORM
WORM
WORM
16
HEADEND
SCHEDULING AND ROUTING COMPUTER
30
SUBSCRIBER DISTRIBUTION NODE
24
34
34
34
MODEM
MODEM
MODEM
MODEM
CH0
CH1
CH 2
CH10
PSTN 56
CATV NETWORK 36
RECEIVERS
40
48
MODEM
CAPTURE MEMORY
46
52
CONTROLLER
BUFFER MEMORY
42
50
DECOMPRESSOR
44
KEYPAD
54
40

FIG. 2.

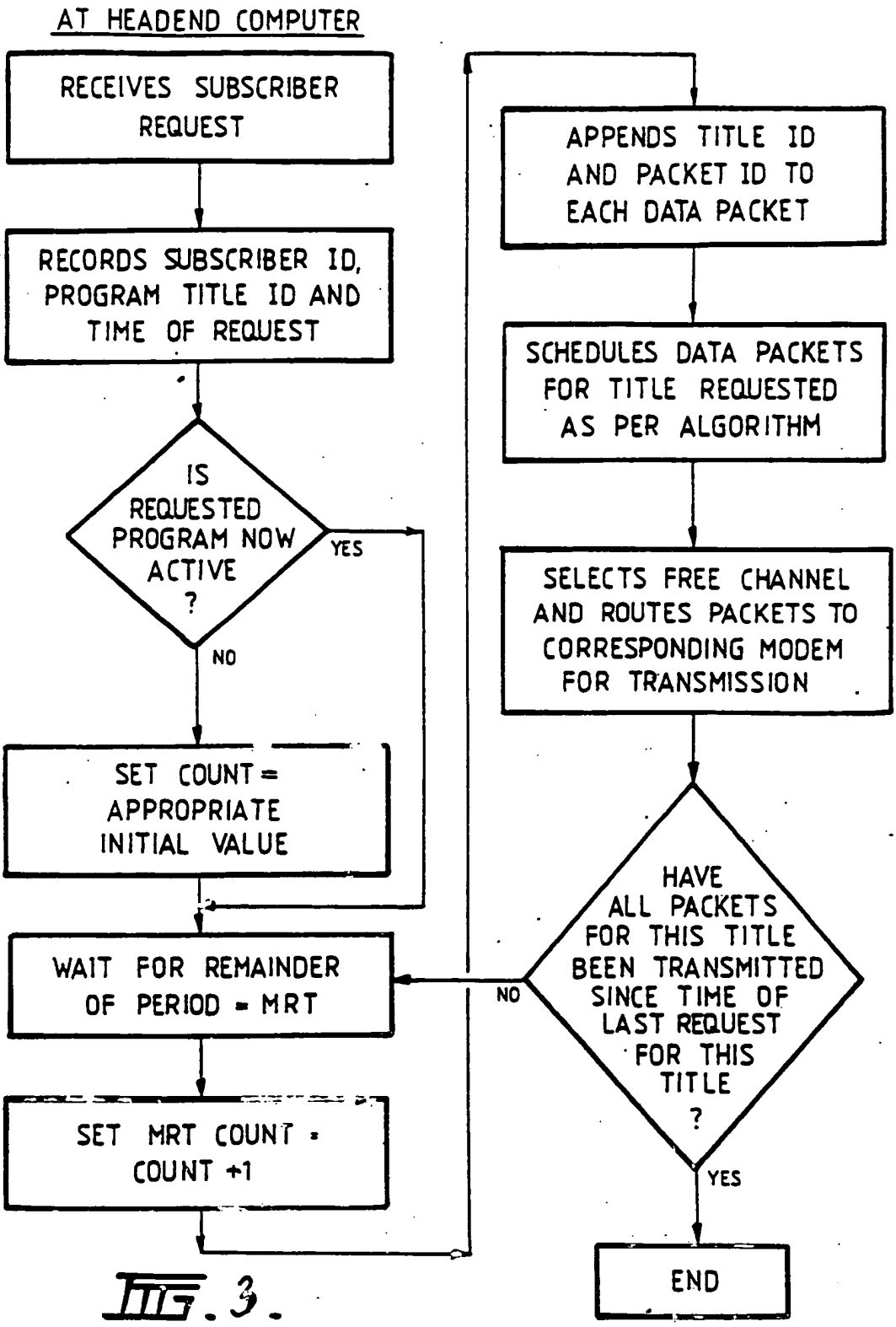
AT HEADEND COMPUTER
RECEIVES SUBSCRIBER REQUEST
RECORDS SUBSCRIBER ID, PROGRAM TITLE ID AND TIME OF REQUEST
IS REQUESTED PROGRAM NOW ACTIVE ?
YES
NO
SET COUNT = APPROPRIATE INITIAL VALUE
WAIT FOR REMAINDER OF PERIOD = MRT
SET MRT COUNT = COUNT +1
APPENDS TITLE ID AND PACKET ID TO EACH DATA PACKET
SCHEDULES DATA PACKETS FOR TITLE REQUESTED AS PER ALGORITHM
SELECTS FREE CHANNEL AND ROUTES PACKETS TO CORRESPONDING MODEM FOR TRANSMISSION
HAVE ALL PACKETS FOR THIS TITLE BEEN TRANSMITTED SINCE TIME OF LAST REQUEST FOR THIS TITLE ?
NO
YES
END

FIG. 3.

AT RECEIVER

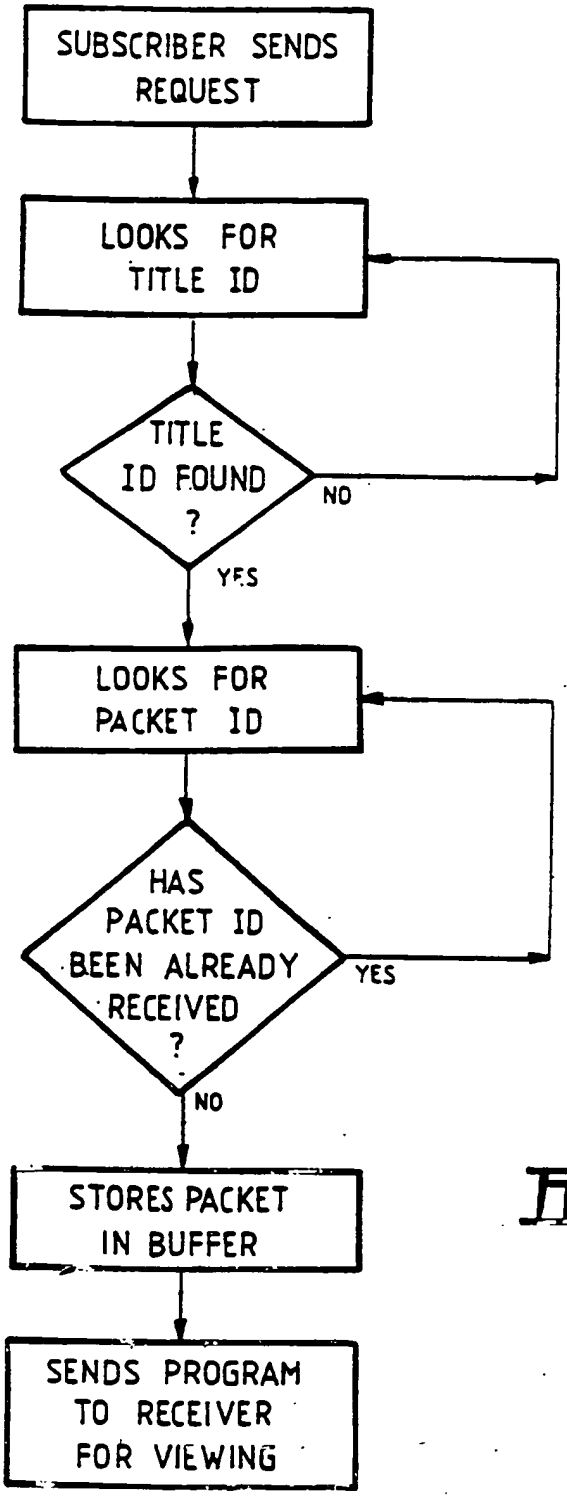

FIG. 4.

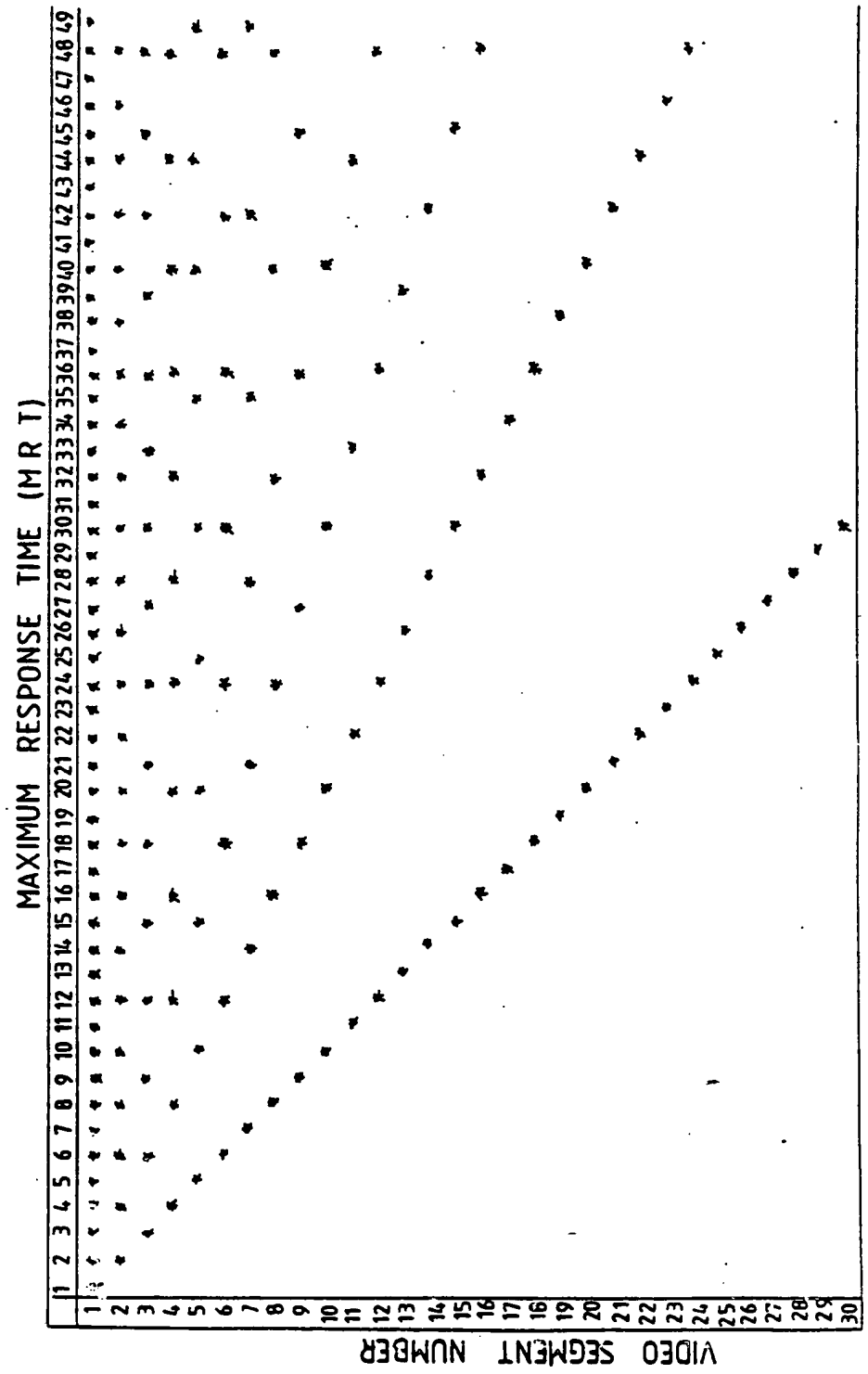

FIG. 5.

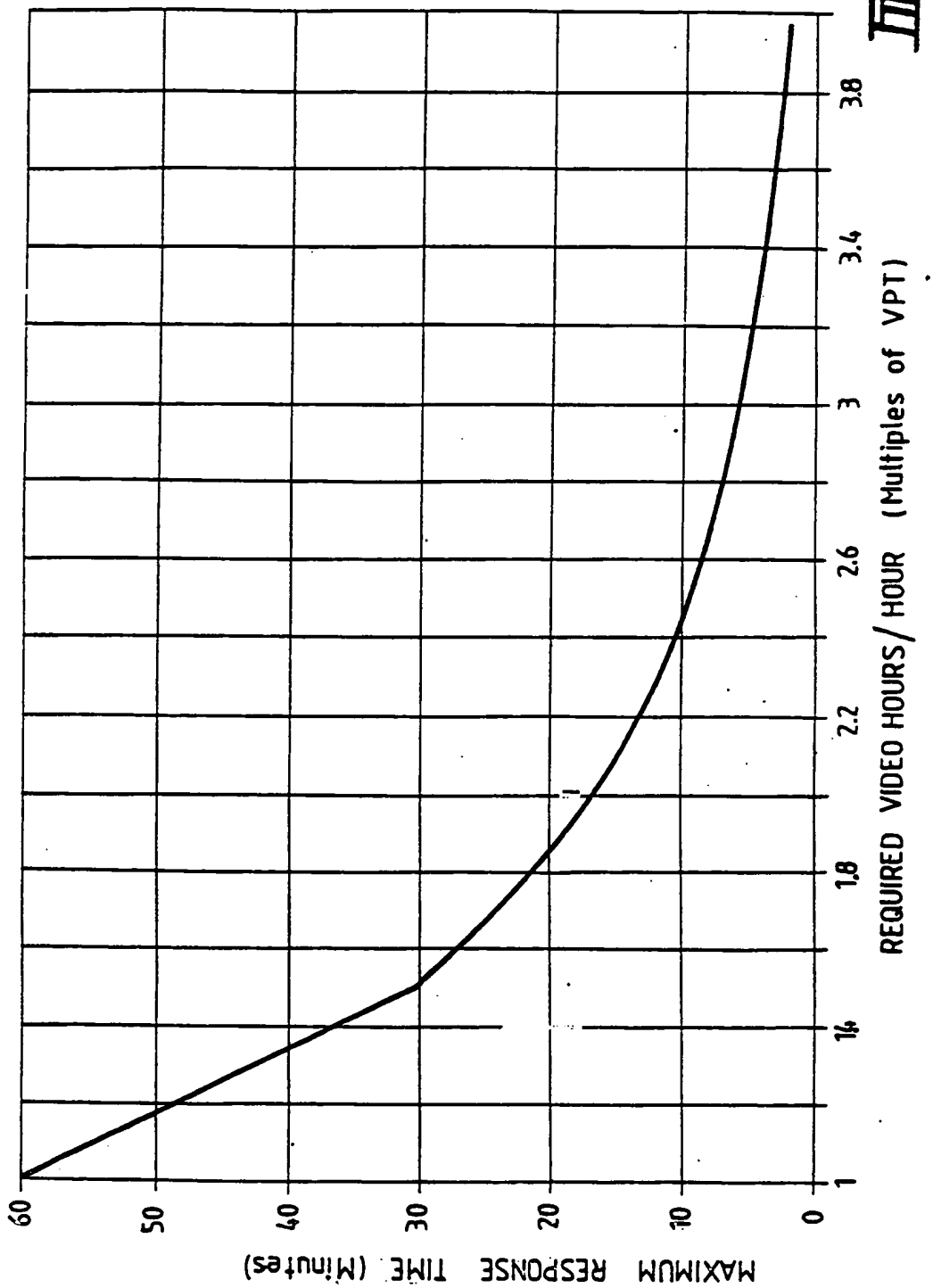
MAXIMUM RESPONSE TIME (Minutes)
60
50
40
30
20
10
0
REQUIRED VIDEO HOURS/HOUR (Multiples of VPT)
1
1.4
1.8
2.2
2.6
3
3.4
3.8

FIG. 6.

INTERNATIONAL SEARCH REPORT

International Application No. PCT/AU 90/00370

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 6

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[5] H04H 1/00, H04N 7/167, G11B 27/36

II. FIELDS SEARCHED

Minimum Documentation Searched 7

Classification System	Classification Symbols
IPC	H04H 1/00, H04N 7/16, 7/167, G11B 27/36

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 8

AU : IPC as above; Australian Classification 05.42

III. DOCUMENTS CONSIDERED TO BE RELEVANT 9

Category*	Citation of Document, 11 with indication, where appropriate, of the relevant passages 12	Relevant to Claim No 13
X	US,A, 4849817 (SHORT) 18 July 1989 (18.07.89) See Figs 5-7, column 8 line 60 to column 9 line 54	(1,8,13,16)
X	US,A, 4847690 (PERKINS) 11 July 1989 (11.07.89) See Figs 5-7, column 8 line 27 to column 9 line 21	(1,8,13,16)
X	US,A, 4821101 (SHORT) 11 April 1989 (11.04.89) See Figs 5-7, column 8 line 24 to column 9 line 18	(1,8,13,16)
X	EP,A, 343930 (SONY CORPORATION) 29 November 1989 (29.11.89) See Figs 1,6,9,11, page 5 lines 5 to 47, page 6 lines 16 to 29, page 9 lines 40 to 57	(1,8,13,16)
A	US,A, 4593318 (ENG et al) 3 June 1986 (03.06.86) See Figs 1,13 and Abstract (continued)	

* Special categories of cited documents: 10

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
9 November 1990 (09.11.90)	16 November 1990
International Searching Authority	Signature of Authorised Officer
Australian Patent Office	R. TOLHURST

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	US,A, 4887152 (MATSUZAKI et al) 12 December 1989 (12.12.89) See Fig 1 and column 1 line 40 to column 2 line 3	

V. [ ] OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE 1

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.[ ] Claim numbers ..., because they relate to subject matter not required to be searched by this Authority, namely:

2.[ ] Claim numbers , because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3.[ ] Claim numbers ..., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4 (a):

VI. [ ] OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING 2

This International Searching Authority found multiple inventions in this international application as follows:

1.[ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.[ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.[ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. [ ] As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

[ ] The additional search fees were accompanied by applicant's protest.

[ ] No protest accompanied the payment of additional search fees.

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON
INTERNATIONAL APPLICATION NO. PCT/AU 90/00370

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Members		
US 4849817	AU 11742/88	AU 29639/89	EP 279411
	JP 63226182	US 4821101	EP 326830
	JP 2192281		
US 4847690	AU 11753/88	EP 279410	JP 63231942
US 4821101	AU 11742/88	AU 29639/89	EP 279411
	JP 63226182	US 4849817	EP 326830
	JP 2192281		
EP 343930	AU 34972/89	EP 343930	JP 2096982
US 4593318	EP 130693	ES 533073	ES 8503465
	JP 60019375		
US 4887152	AU 10779/88	AU 597143	BR 8800343
	EP 277015	JP 63187984	JP 63209243

END OF ANNEX